WHAT IS CLAIMED IS:

1. A receiving beam-forming method comprising the steps of:

dividing a plurality of ultrasonic transducer elements arranged in an arc-shaped form into multiple blocks according to directions in which receiving beams are formed;

repeatedly sampling signals received by the individual ultrasonic transducer elements at a specific scanning frequency;

selecting sample data derived from different scanning cycles for the individual blocks; and

forming the receiving beams using the selected sample data.

2. The receiving beam-forming method according to claim 1, wherein the signals received by the multiple ultrasonic transducer elements are pulse signals whose pulselength is shorter than the extent of the multiple ultrasonic transducer elements arranged in the arc-shaped form as measured along the direction of each of the receiving beams.

3. The receiving beam-forming method according to claim 1, wherein the signals received by the multiple ultrasonic transducer elements are growing waves whose amplitude gradually increases or damped waves whose amplitude gradually decreases.

4. A receiving beam-forming method in which a plurality

of ultrasonic transducer elements arranged in an arc-shaped form as recited in claim 1 are obtained by selecting an arc-shaped part of multiple ultrasonic transducer elements which are arranged in a circular form, wherein receiving beam-forming direction is rotated by successively switching the selection of said arc-shaped part of the ultrasonic transducer elements.

5. A receiving beam-forming method comprising the steps of:

dividing a plurality of ultrasonic transducer elements arranged in a linear form into multiple blocks;

repeatedly sampling signals received by the individual ultrasonic transducer elements at a specific scanning frequency;

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selecting sample data derived from different scanning cycles for the individual blocks; and

forming a receiving beam in a specific direction using the selected sample data.

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6. The receiving beam-forming method according to claim 5, wherein the signals received by the multiple ultrasonic transducer elements are pulse signals whose pulselength is shorter than the extent of the multiple ultrasonic transducer elements as viewed from said specific direction.

7. The receiving beam-forming method according to claim 5, wherein the signals received by the multiple ultrasonic transducer elements

transducer elements are growing waves whose amplitude gradually increases or damped waves whose amplitude gradually decreases.

8. The receiving beam-forming method according to claim

a 5, ~~6 or 7~~, wherein selection of the scanning cycles for the individual blocks is altered according to the angle between the direction of the receiving beam and the ultrasonic transducer elements arranged in the linear form.

9. A receiving beam-forming method comprising the steps of:

Fig. 6

entering sample data obtained by sampling signals received by a plurality of ultrasonic transducer elements arranged in a linear form at a specific scanning ~~frequency~~ cycles;

storing said sample data derived from multiple scanning cycles;

dividing the multiple ultrasonic transducer elements into multiple blocks;

reading out the sample data derived from different scanning cycles for the individual blocks;

producing a continuous sample data train by shifting the phase of the individual sample data; and

forming a receiving beam in a specific direction using the sample data.

10. A receiving beam-forming apparatus comprising:

a multiplexer which multiplexes echo signals received

Fig. 6

by multiple ultrasonic transducer elements arranged in an arc-shaped form on a receiving transducer into a smaller number of signal lines than the number of the ultrasonic transducer elements;

an A/D converter which repeatedly samples the echo signals received by the individual ultrasonic transducer elements at a specific scanning frequency and outputs complex-valued sample data; and

a signal processor which divides the multiple ultrasonic transducer elements into multiple blocks according to directions in which receiving beams are formed, selects the sample data derived from different scanning cycles for the individual blocks, and forms the receiving beams in said directions using the selected complex-valued sample data.

11. The receiving beam-forming apparatus according to claim 10, wherein said receiving transducer is constructed of multiple ultrasonic transducer elements arranged in a circular form, and said signal processor obtains said multiple ultrasonic transducer elements arranged in the arc-shaped form by selecting an arc-shaped part of the ultrasonic transducer elements arranged in the circular form and rotates receiving beam-forming direction by successively switching the selection of said arc-shaped part of the ultrasonic transducer elements.

12. A matched filter which selects an arc-shaped part of ultrasonic transducer elements from a plurality of ultrasonic transducer elements arranged in a circular form and forms a receiving beam oriented in a central direction of said arc-shaped part, said matched filter comprising:

a shift register which has as many stages as a number given by (the number of said ultrasonic transducer elements arranged in the circular form) x (n-1) + (the number of said ultrasonic transducer elements of the arc-shaped part) and stores signal trains obtained from said ultrasonic transducer elements of the arc-shaped part among signal trains of multiple scanning cycles sequentially entered from said ultrasonic transducer elements arranged in the circular form in the order of a signal train of the nth scanning cycle, a signal train of the (n-1)th scanning cycle,...., a signal train of the second scanning cycle and a signal train of the first scanning cycle;

a plurality of multipliers which divide said ultrasonic transducer elements of the arc-shaped part into n blocks according to the direction in which the receiving beam is formed, selects signals of the ultrasonic transducer elements of a block closest to the beam direction from the signal train of the nth scanning cycle, selects signals of the ultrasonic transducer elements of a block next to the block closest to the beam direction from the signal train of

the (n-1)th scanning cycle,....., selects signals of the ultrasonic transducer elements of a block next to a block most distant from the beam direction from the signal train of the second scanning cycle, selects signals of the ultrasonic transducer elements of the block most distant from the beam direction from the signal train of the first scanning cycle, and multiplies the individual signals by corresponding coefficients; and

an adder which adds up results of multiplications performed by the individual multipliers and outputs the sum as correlation data.

13. A matched filter which selects an arc-shaped part of ultrasonic transducer elements from multiple ultrasonic transducer elements arranged in a partially cutaway circular form and forms a receiving beam oriented in a central direction of said arc-shaped part,

wherein n number of shift registers having as many stages as the number of said multiple ultrasonic transducer elements arranged in the partially cutaway circular form and shift registers having as many stages as the number of said ultrasonic transducer elements of the arc-shaped part are connected in parallel, and said matched filter stores signal trains obtained from said ultrasonic transducer elements of the arc-shaped part among signal trains of multiple scanning cycles sequentially entered from said ultrasonic transducer

elements arranged in the partially cutaway circular form in the order of a signal train of the nth scanning cycle, a signal train of the (n-1)th scanning cycle,...., a signal train of the second scanning cycle and a signal train of the first scanning cycle while loading them in parallel between the individual shift registers, said matched filter comprising:

a plurality of multipliers which divide said ultrasonic transducer elements of the arc-shaped part into n blocks according to the direction in which the receiving beam is formed, selects signals of the ultrasonic transducer elements of a block closest to the beam direction from the signal train of the nth scanning cycle, selects signals of the ultrasonic transducer elements of a block next to the block closest to the beam direction from the signal train of the (n-1)th scanning cycle,....., selects signals of the ultrasonic transducer elements of a block next to a block most distant from the beam direction from the signal train of the second scanning cycle, selects signals of the ultrasonic transducer elements of the block most distant from the beam direction from the signal train of the first scanning cycle, and multiplies the individual signals by corresponding coefficients; and

an adder which adds up results of multiplications performed by the individual multipliers and outputs the sum

as correlation data.

14. The matched filter according to claim 12 ~~or 13,~~ wherein the signal trains entered from said multiple ultrasonic transducer elements are complex-valued sample data trains, and wherein said matched filter comprises:

two lines of said shift registers for in-phase data and quadrature data;

four lines of said multipliers and said adder for in-phase data x in-phase coefficient, quadrature data x quadrature coefficient, in-phase data x quadrature coefficient, and quadrature data x in-phase coefficient; and

an output section which determines an in-phase portion of a correlation value by subtracting the product of in-phase data x in-phase coefficient from the product of quadrature data x quadrature coefficient, and determines a quadrature portion of the correlation value by adding the product of in-phase data x quadrature coefficient and the product of quadrature data x in-phase coefficient.

15. The matched filter according to claim 12, ~~13 or 14,~~ wherein multiple sets of the coefficients are provided such that the receiving beam can be focused at varying distances.

16. A receiving beam-forming apparatus in which echo signals received by multiple ultrasonic transducer elements are sampled at a specific scanning frequency to obtain sample data, said receiving beam-forming

apparatus comprising:

a memory which stores the sample data derived from multiple scanning cycles; and

a beamformer which divides the multiple ultrasonic transducer elements into multiple blocks, reads out the sample data derived from different scanning cycles for the individual blocks from said memory, and forms a receiving beam in a specific direction using the individual sample data which have been read out.

17. The receiving beam-forming apparatus according to claim 16, wherein selection of the scanning cycles for the individual blocks is altered according to the angle between the direction of the receiving beam and the ultrasonic transducer elements arranged in the linear form.

18. The receiving beam-forming apparatus according to claim 16 ~~or 17~~, wherein said beamformer is a matched filter which forms the receiving beam in the specific direction by multiplying the individual sample data by specific coefficients, and said matched filter is provided with multiple sets of the coefficients so that the receiving beam can be focused at varying distances.

19. A receiving beam-forming apparatus in which echo signals received by multiple ultrasonic transducer elements arranged in a linear form are sampled at a specific scanning frequency to obtain sample data, said receiving beam-forming

apparatus comprising:

a memory which stores the sample data derived from multiple scanning cycles;

a sampling plane generator which produces a continuous sample data train of a sampling plane of a specific angle by shifting the phase of or interpolating the sample data derived from the multiple scanning cycles; and

a beamformer which forms a receiving beam in a specific direction using the sample data.

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20. A receiving beam-forming apparatus which repeatedly samples echo signals received by multiple ultrasonic transducer elements at a specific scanning frequency and forms a receiving beam using sample data obtained by sampling the echo signals in multiple scanning cycles.

21. A sonar system which emits an ultrasonic search pulse signal and receives echo signals by receiving beams formed successively and oriented in successively varying directions, said sonar system comprising:

a plurality of transducer elements for receiving echo signals of a specific frequency;

a plurality of A/D converters which convert analog signals supplied from said transducer elements into digital form;

means for generating in-phase data of complex-valued

sample data and quadrature data of complex-valued sample data from the digital signals; and

a matched filter for receiving the in-phase data of complex-valued sample data and quadrature data of complex-valued sample data from said generating means and successively forming the receiving beams in different directions.

22. The sonar system as claimed in the claim 21 wherein the matched filter comprises a first memory unit for storing complex valued sample data resulting from echo signals, a second memory unit for storing complex coefficients, a plurality of multipliers for multiplying the sample data with the corresponding complex coefficients respectively, an adder for adding the output signals from the multipliers, and an amplitude detector for producing based on the output signals of the adder output signals forming a reception beam.

23. The sonar system as claimed in the claim 21 wherein the plurality of transducer elements are arranged on the surface of a sphere at space intervals.

24. A sonar system which emits an ultrasonic search pulse signal and receives echo signals by receiving beams formed successively and oriented in successively varying directions, said sonar system comprising:

a plurality of groups of transducer elements for

receiving echo signals of a specific frequency;

a plurality of multiplexers which multiplex signals entered successively from each of said groups of the transducer elements into a smaller number of channels than the number of said transducer elements, wherein said multiplexers operate with synchronized switching timing;

a plurality of A/D converters which convert analog signals entered respectively and individually from said multiplexers into digital form, wherein said A/D converters operate with synchronized sampling timing;

means for generating in-phase data of complex-valued sample data and quadrature data of complex-valued sample data from the digital signals; and

a matched filter for receiving the in-phase data of complex-valued sample data and quadrature data of complex-valued sample data from said generating means and successively forming the receiving beams in different directions,

the matched filter comprising a first memory unit for storing complex valued sample data resulting from echo signals, a second memory unit for storing complex coefficients, a plurality of multipliers for multiplying the sample data with the corresponding complex coefficients respectively, an adder for adding the output signals from

the multipliers, and an amplitude detector for producing based on the output signals of the adder output signals forming a reception beam.

25. The sonar system as claimed in the claim 24 wherein the plurality of the transducer elements are arranged on the surface of a sphere at space intervals.

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